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CITRUS FRUIT CULTURE.

By J. W. MILLS.

A CITRUS FRUIT REGION IN SOUTHERN CALIFORNIA.

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TABLE OF CONTENTS.

PREFATORY NOTE.

By CHARLES H. SHINN, Inspector of Stations.

The University of California Experiment Station has been testing citrus fruits for many years, beginning at the Central station (where soil and climate are very ill-adapted to these fruits) and continuing at the substations as fast as they were established. The results of this work, to some extent printed in annual reports, have been mainly obtained, as was to be expected, in Southern California, the best substation for this work being situated there, in the Chino Valley. At other substations, however, some useful results have been reached, which may be briefly stated.

At the Sierra Foothill substation, Amador County, three varieties of oranges—Konah, Malta Blood, and Washington Navel—on sweet-stock, were planted in 1888. Florida sour-stock seedlings were put in later; then some hardy Japanese stocks (*Citrus trifoliata*). The soil where the first planting was done was poor and rocky, and the trees were several times badly frosted, so that by 1896 this trial was considered a failure, only the Japanese long-fruited "Cumquat," or gooseberry orange, and the dwarf Oonshiu (both on *trifoliata* stock) having succeeded. These, however, have done so well that their culture is strongly recommended for gardens at this elevation (about 2,000 feet) in the Sierra foothills. For standards the sour-stock appeared to be decidedly hardier, and in every way better than the sweet-stock. A new and more sheltered location was chosen on better soil, and here a small orange grove has been established, with every prospect of success.

Oranges were also planted at the San Joaquin Valley substation, near Tulare, and at the Southern Coast Range substation, near Paso Robles. At the latter point they utterly failed, both soil and climate proving totally unsuitable for semi-tropic trees; this fact was therefore published, and no further experiments made. At the former point, Tulare, some of the orange trees have grown, though often heavily cut back by frost. The sour-stock proves most resistant to alkali, and as a rule hardier. The dwarf deciduous orange of Japan (*Citrus trifoliata*) grows and fruits in even stronger alkali, and therefore is recommended as a stock for gardeners in such localities.

The planting of citrus fruits at the Southern California substation began in the spring of 1891, when the foreman set out eight varieties of orange, then three years from bud, on sour-stock, and eight varieties on sweet-stock; also three varieties of citron and three of lemon, all on sweet-orange stock. The tract was well situated, though far from the hills, and on lower ground than the best conditions require. Additions were made to the orchard each following year, and by 1896 about twenty-five varieties of citrus fruits were in bearing. At the present time, the orchard includes every variety of promise which can be obtained in California or from the Department of Agriculture at Wash-

ington, besides local seedlings under trial. Some kinds have been discarded and trees regrafted. The orchard is well kept, healthy, and free from insect pests; it constitutes a good working model for an orange grove under valley conditions. A part of the illustrations which accompany this bulletin are from this orchard.

But the culture of citrus fruits has become the leading industry of many districts of California, and it is being developed with surprising skill and energy by very capable horticulturists, some of whom have been almost a lifetime in this occupation. It is therefore essential to the truthfulness of any inquiry into the present problems of citrus-fruit culture that a wider range of observation than that afforded by the substation tract of thirty acres should be taken. Mr. J. W. Mills, foreman of this substation since 1893, was therefore sent out to visit some of the best orchards in leading orange districts of Los Angeles, San Bernardino, and Riverside counties, and to compare the station experience with that of successful commercial growers. The results should possess interest for those who wish to plant citrus fruits in any part of California, since the conditions of soil and climate at Cloverdale, Calistoga, Palermo, Porterville, and other northern and central orange-growing points, while in some respects quite different from those of the southern orange-growing counties, are sufficiently similar to make careful observations in any part of California valuable. Much more complete studies of local conditions have been made in the southern citrus districts than in other parts of the State, and some of the conclusions herein reached may need modification as respects northern districts when an equal amount of local experience shall have been there accumulated.

In citrus fruit districts the high price of land that is known to be well situated, of the best quality, and supplied with water, leads men to extend citrus culture far beyond its natural limits, upon unsuitable soils and into frosty localities. The marked recent advance in average prices of citrus fruits and of well-planted orchards has also caused hasty and careless planting, even in well-established districts. Many old trees are bearing less satisfactory crops than heretofore, and various plant diseases add to the anxiety of the orchardists. Technical knowledge and a high degree of horticultural skill are every year more essential to the prosperity of each individual orange-grower.

The observations of many successful citrus-fruit orchardists have been placed at the service of the station in preparing this bulletin, partly in obtaining the history of the older groves and of the origin of some new varieties, partly in securing needful details respecting more recent practice in planting and culture on a commercial scale, in representative districts. Credit has been given in all cases for such assistance, without which this bulletin would have been merely a record of experiments in one orchard. The discussion is almost wholly devoted to problems of orange culture, but some references are made to the lemon.

The following pages have been condensed and edited from the manuscript furnished by Mr. J. W. Mills, foreman of the substation. All the illustrations are from photographs taken by Mr. Mills.

CITRUS FRUIT CULTURE.

Varieties, Stock, Planting From Nursery, Re-budding Old Orchards, Cultivation, Irrigation, Diseases, Remedies, and Other Practical Problems.

By J. W. MILLS.

VARIETIES OF ORANGES.

The *Washington Navel*, which is so well known that it hardly needs especial description, is still the only orange that the market demands in large quantities. There are, however, several sub-varieties of the fruit, none of which, so far as tested commercially, surpass the best of the original type. The quality of this orange varies according to soil and location. Its fortunate tendency to sport gives promise of ultimate improvement over the original type, and several new varieties of Navel oranges have been selected and are being introduced.

Thompson's Improved Navel.—The first important variation from the Navel was "Thompson's Improved," introduced by Mr. A. C. Thompson, of Duarte, Los Angeles County. The introducer claims that this variety is not a sport, but is a special creation of his own, accomplished by the division and union of buds of select Navel, St. Michael, and Blood oranges. (See Mr. Thompson's note on his Navelencia orange, page 7.) The practical difficulties in such division and union are so great that many more experiments along this line are necessary to confirm or disprove Mr. Thompson's claim of the origin of this variety. It is a beautiful fruit, which has been eagerly sought after and widely planted. There are conflicting opinions as to its value as a shipping variety in different sections of the southern citrus belt. Mr. C. C. Buffington, of Corona, an extensive buyer and shipper of citrus fruits, says: "There has always been a doubt in my mind as to its being a practical variety, owing to its thin skin and tender pulp."

Mr. H. D. Briggs, of Azusa, writes: "My five years' experience is that I consider the Thompson superior to the Washington Navel, for the following reasons: It has a smoother skin; it has a thinner skin; it is higher colored; it is a heavier bearer at the same age; the tree is a little larger and more upright at the same age; it stands shipping fully as well. The only fault I have to find with it is that it dropped far heavier last spring, but still the trees have twice the number of oranges left that the Washington Navels of the same age have. The soil is a rich, sandy loam that is predisposed to grow a large, rather coarse Washington Navel."

The fruit of the Thompson's Improved Navel as grown at the Pomona substation does not seem equal to the best type of Washington Navel. This may be due to its thinner skin, which is more injured by the frost. A temperature of 25° Fahr. is almost sure to be reached some time before the fruit is fully ripe, and this will usually injure a thin-skinned early or mid-season orange where a thick-skinned one would be but slightly injured. The Thompson's Improved, therefore, is not recommended for planting in locations that are frequently subject to severe frost.

The thin skin of Thompson's Improved Navel does not necessarily detract from its shipping qualities, but there may be other qualities that make it a poor shipper, such as a loose attachment of the divisions of the fruit. The St. Michael Paper-Rind has a much thinner skin and is an excellent shipper.

Golden Nugget Navel.—This sub-variety is a new, early kind that was found to be sweet and juicy on the 20th of November, at Glendora, Los Angeles County. There is but one tree of full-bearing age, and it is in a favorable locality for early ripening. Mr. J. P. Englehardt, of Glendora, in whose orchard it stands, writes as follows: "The tree was purchased among a lot of nursery stock at Alhambra, ten years ago. It looked like all the rest, but it would not grow, and was stunted in the first place. I cut it back to almost nothing, when it put forth leaves of a different appearance, and subsequently bore fruit that differed from the others."

Mr. R. M. Teague, of San Dimas, who is propagating this variety, says: "This orange ripens very early in the season, and is a very thin-skinned, nice-appearing fruit. There being only one tree in fruit, it is hard to state just what the average time of ripening will be; all we can say is that it is very early."

Golden Buckeye Navel.—This sub-variety is reported to be a sport from the Washington Navel. The rind is as thin as that of the Tan-

gerine, but, unlike the latter, it adheres so closely to the pericarp that the divisions can be plainly seen through it after the fruit has been picked a few days, giving it the appearance of a nutmeg melon. Upon inquiry, Mr. Teague, of San Dimas, writes: "The orange tree you mention as growing in Pomona originally came from here; there happened to be one branch that 'sported' to this in the twenty-acre grove here at San Dimas. These oranges ripen very early, are very thin-skinned, with a slight pineapple flavor, and all pack as 'fancies.' The only objection to this orange is the color of its skin, which is a pale yellow, and so it seems to be a cross between a Washington Navel and a St. Michael."

Navelencia.—This orange is a recent introduction of Mr. A. C. Thompson, of Duarte, the originator of Thompson's Improved. Some growers say that trees of the Navelencia grown by them compare favorably in size, when three years old, with five-year-old Thompson's Improved, when both are grown under the same conditions. The Navelencia tree is a more upright grower than the original Washington Navel. When Thompson's Improved is sweet enough to be pleasant to eat, Navelencia is still unfit to eat. While its lateness and other desirable qualities will probably give it a place with citrus-growers, it is not likely that it will hang on the tree and retain its good qualities as long as the true Valencia.*

Valencia Late.—The Valencia orange ripens during May and June, and commercially stands next to the Washington Navel. It will, perhaps, never be shipped as extensively, because it comes in at the end of the orange season when early deciduous fruits are in market. But this variety has the additional advantage of keeping well when left all summer on the tree, and can thus be held over for the early winter and holiday trade. Early new varieties will probably, in time, take its place

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*Mr. Thompson's account of the origin of this variety is given by himself as follows: "The Navelencia is an equal production of one half Valencia and the other half Thompson's Improved Navel orange. In 1890 I made several crosses, but this was the only one that made a complete union. In many cases one of the buds so spliced together would start several days before the other made a move, so both germs grew separate; in some cases one half died, in others both barks would unite, but only one germ would start; this one seemed to grow, both germs uniting, both barks catching quickly, and made one shoot. This operation has to be watched every day with a powerful glass after the fifteenth day from the time the buds are inserted in the young trees in the nursery, to make sure that both germs have united; the half buds must be of equal size and age, and of equal ripeness, and concave on the germ edges to fit the convexity of the tree, when held tightly together. Wax over lightly after pressing them close to the tree, covering the whole cut with wax cloth for fifteen days, then begin examining as to the progress, re-wrapping every time until you are satisfied that the experiment is a success."

for this purpose, as it assumes a greenish color when left on the tree after its natural period of maturity.

In regard to the prospects for future plantings of the Valencia Late, Mr. A. H. Naftzger, president and manager of the Southern California Fruit Exchange, writes as follows: "Since they come at a time when the demand for oranges is, in the nature of things, limited, I doubt if a larger acreage than is now coming forward in California gives good promise of satisfactory results."

Redlands Early Orange.—This is an early seedling found in a nursery row, and now being tested by Mr. H. H. Smith, of Redlands. It ripens for the Thanksgiving trade, at which time it has high color, and is very sweet, but thought by some growers to lack in flavor. Samples exhibited at the Farmers' Club Institute held at Riverside December 20, 1900, were fully matured and more palatable than any other variety shown at that time. The oranges are small, averaging 250 or even more to the box.

Seedlings.—While no one now thinks of planting seedlings, yet some of the best paying groves are composed of these, as the immense size that the trees attain at the age of fifteen or twenty-five years makes them enormously productive. Individual trees in old and well-kept groves have been known to produce forty boxes of oranges in one season. Seedling trees that are planted twenty feet apart, and well cared-for, will become crowded when they are twenty or twenty-five years old. The side branches then make a feeble growth, the trees become tall, and produce fruit chiefly on the upper part. Under such circumstances the expense of gathering is increased and there is a greater proportion of poor fruit. The trees should be pruned so as to admit more light to the lower branches, which is sometimes done by shortening-in the side limbs and heading-back. But a better way is to bud-over, and remove the tops of every other tree, so that the new tops will alternate with the tall seedling trees both ways in every row. Seedlings sixteen years old, when budded have each produced eight boxes of fine Washington Navels during the next four years, while the alternating seedling trees, not budded, produced more fruit per tree and of much better quality than they did before the others were budded. The accompanying photograph (plate 1) shows the splendid growth of a four-year-old Navel orange top on a sixteen-year-old seedling. The tree was beheaded six weeks after budding, and was protected from frost by palm leaves.

Blood Oranges.—Ruby is the earliest of the desirable varieties of blood oranges, and is a prolific bearer. The fruit is rather small at the

Pomona substation, but it has a high color and fine flavor. Malta Blood is larger than the Ruby, but it bears less and is a poorer orange. There is only a light demand for either variety.

Mediterranean Sweet.—This kind was at one time popular, but its tendency to bear small crops in certain sections, even under the best of care, makes it untrustworthy. Numbers of Mediterraneans are being budded-over to Washington Navels.

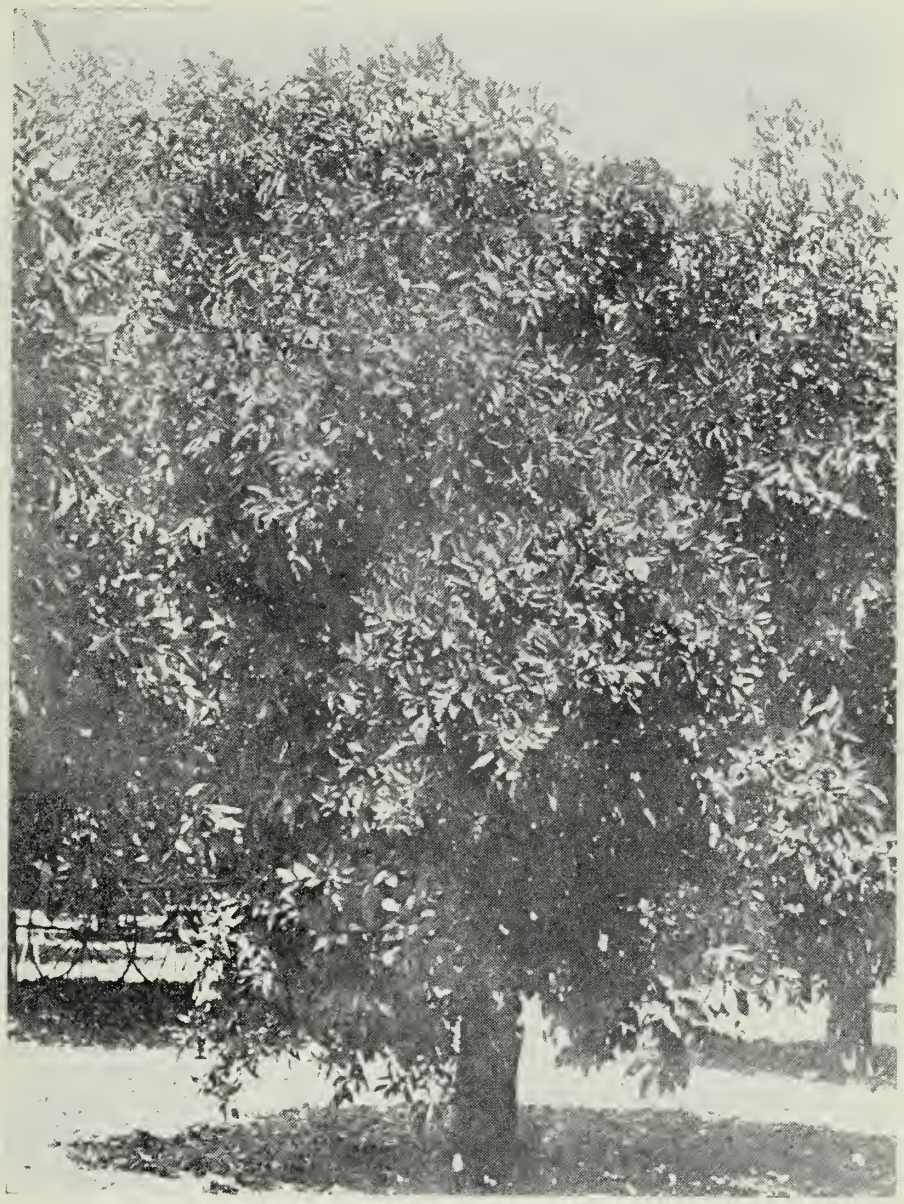


PLATE 1. OLD SEEDLING ORANGE BUDDED TO WASHINGTON NAVEL.
Four-year-old top on sixteen-year-old seedling.

St. Michael Paper-Rind.—This is an old variety, which, though strongly approved by some growers, is not now being planted to any appreciable extent for commercial purposes. It is a small, late variety, with extremely thin rind, and, as it is of high quality, can be recommended for family orchards.

Miscellaneous Varieties.—Many varieties of oranges that have no recognized commercial standing have long been classed as "seedlings"

by the trade, and therefore are of lessening importance in citrus-fruit districts. Nevertheless, new varieties from all parts of the world are worth testing, together with promising sorts of local origin, and while very few of them can expect to gain a place in commerce, many will be useful in gardens. The required standards, as shown by citrus fairs, are each year more rigorous. These standards are given at the end of this bulletin.

THE STOCK FOR CITRUS FRUITS.

Little attention has been given in California to the hardiness of different budding-stocks. At a time when some sour-orange stocks

a *b* *c*

PLATE 2. Root-Systems of Seedlings.

a. Florida Sour-Seedling. *b*. Pomelo Seedling. *c*. Common Sweet-Seedling. All of the same age—18 months.

were imported from Florida, a few trees budded on this root were planted; but the demand for citrus fruit trees rapidly increased, and horticultural quarantine laws came into operation against importation, so that the use of stocks grown from native sweet-seedlings became general. This is still considered "as good as any" by nearly all of our orchardists. Some use pomelo (*Citrus aurantium* var. *Pomelanus*, Willd.), and a few use the native wild orange of Florida (*C. vulgaris* var. *Bigaradia*, Risso).

The root-systems of these three stocks vary considerably, even in the seedling-beds. At the age of eighteen months from the seed there is little difference between the root-systems of the Florida sour and the pomelo (plate 2, *a* and *b*), though the former is better balanced. The sweet-orange seedling (plate 2, *c*) is but moderately well supplied with fibrous roots, which soon develop at the expense of the crooked and irregular tap-root.

Sweet-Stock Root-System.— In a porous soil which has been well watered from the time of planting, the main mass of the root-system of bearing trees on sweet-orange stock concentrates in a horizontal layer about eighteen inches thick, the top of which is eight or ten inches from the surface. This is well illustrated by the accompanying view of the main

PLATE 3. MAIN ROOT-SYSTEM OF A THIRTY-YEAR-OLD SWEET-SEEDLING.

roots of a tree that had grown in a rich, sandy loam for thirty years where artesian water was cheap and abundant and was freely used during the entire life of the tree. (See plate 3.) Two hundred trees that were pulled from the ground in the same orchard showed the same kind of a root-system. Over-irrigation might be thought responsible for this shallow rooting, but ten acres of the same variety that grew for sixteen years in a soil containing more sand and gravel than that just described, where water was always scarce and expensive, had the root-systems distributed in much the same way. (See plate 4.) In the heavy soil of Riverside the same condition prevails. In short, the general experience on all kinds of soils and under different methods of irrigation shows that *it is the nature of the sweet-orange seedling to form a shallow root-system.*

Careful studies of the root-systems of sweet-oranges have been made at the Pomona substation, where the trees have always received deep and thorough irrigation, the water having been allowed to run from forty-eight to seventy-two hours at a time. Deep irrigation was here followed by deep cultivation from the time the trees were planted, and this somewhat discouraged but did not remove the shallow-rooting tendency. The ten-year-old Washington Navel on sweet-seedling stock, illustrated in plate 5, fig. 1, had three of its heaviest lateral roots, starting out six inches below the surface, severed by the plow, at a distance of two feet from the tree and of ten inches below the surface. (*a* in plate 5.) At this point a secondary lateral (*b*) developed, and descended at an angle of about sixty degrees from the perpendicular, until it reached a depth of two feet, when it assumed an almost hori-

PLATE 4. Root and Stem of Sixteen-Year-Old Orange Tree on Light Sandy Soil. Has always been short of water.

zontal position. As no fertilizers have ever been applied to the orchard there could have been no influence from that source which would cause the roots to come near the surface. The original tap-root had not penetrated deeper than four feet ten inches (*c* in plate 5). The longest lateral had a total length of fourteen feet, with many turns, at no time going deeper than one foot. From the main laterals were numerous secondary laterals that penetrated from one to two feet, and from these numerous fibrous roots extended through the soil in all directions. To sum this up, *the sweet-orange is a surface-growing stock which has few or no deeply-penetrating roots.*

Advantages of Pomelo Stock.—Nearly all the orange trees now bearing in Southern California are budded on sweet-orange stock, but the pomelo is rapidly taking its place. There is still some prejudice

against this as a budding stock, as some growers think it less hardy than the sweet-orange. It makes, however, a very healthy tree, and is said to stand next in value to the sour, or hardy, stock among Florida growers. The seed of the pomelo is easily obtained, and it germinates more quickly than does orange seed. The root-system of a one-year-old pomelo seedling is excellent, but the tap-root is crooked, like that of the sweet-orange. (See plate 5, fig. 2.) Some of the lateral roots of the

Fig. 1. Fig. 2.

PLATE 5. Root-Systems of Sweet-Orange and Pomelo Stocks.

Fig. 1. Sweet-orange stock; ten years from time of planting.

Fig. 2. Pomelo stock; seven years old.

pomelo soon develop at the expense of the tap-root, making a prodigious growth. A seven-year-old seedling pomelo, whose root-system was studied at the substation, had a tap-root four feet long, making a healthy though small growth, while the largest lateral root started two feet below the surface and extended for a distance of twenty-six feet, or two feet beyond where the next tree was planted, at an average depth of about eighteen inches below the surface. Over ninety per cent

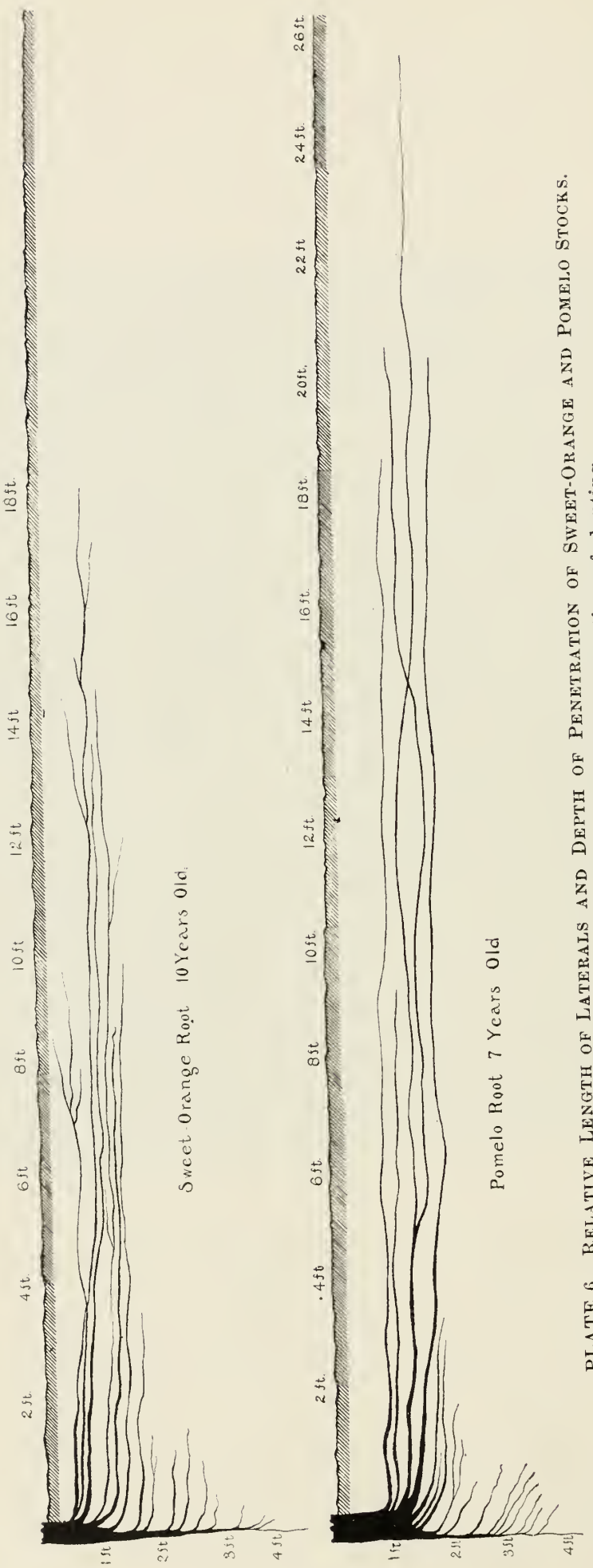


PLATE 6. Relative Length of Laterals and Depth of Penetration of Sweet-Orange and Pomelo Stocks.
Each had deep cultivation and irrigation from time of planting.

of the root-system exposed was found to be confined to a layer between ten inches and two feet below the surface. The accompanying views on plate 5 show the superiority of the pomelo over the sweet-orange in mere root development. The seven-year-old pomelo, figure 2, had proportionately a much larger number of fibrous roots than the ten-year-old sweet-seedling. The pomelo roots ran deeper beneath the surface than the sweet-orange, the majority sinking below fifteen inches. Plates 6 and 8 show drawings of the root-systems of sweet-orange, of pomelo, and of Florida sour stocks, which further illustrate these points.

The Florida Sour-Orange.—The sour-orange stock was introduced into Southern California by Twogood & Cutter, of Riverside, during the early days of citrus planting. It is a very useful budding stock, is called one of the most hardy of the strong-growing citrus fruits, and is used extensively in Florida and Europe in localities where the "foot rot" or "mal di goma" is liable to attack orange trees.

There has been much discussion among orange-growers in California as to the relative merits of sweet- and sour-orange stocks, and even now there seems to be no generally recognized superiority of either. Growers having orchards on sweet-stock claim that it is as good as any, while those having trees budded on sour-stock think the same of them. Disinterested judges have said that they can see no difference where the two stocks have received the best of care. One of the thriftiest Washington Navel groves in the Riverside section is budded on sour-stock, but during its early bearing period this sour-stock grove did not produce as much fruit as did other groves of the same age which were budded on sweet seedlings. In recent years, however, it has been producing abundant crops. On the grounds of the substation Washington Navel trees budded on both varieties of stock have always had the same care, and on an average have produced equally well, when the same stock developed numerous laterals. The deep rooting of a Florida sour-stock at the substation is well illustrated by plate 7, which shows a nine-year-old Washington Navel tree and its sour-stock root-system. The longest and uppermost lateral started six inches below the surface and descended at once at an angle of forty-five degrees until two feet below the surface; then extended in a horizontal position for ten feet from the tree and rose to within eight inches of the surface, when it was cut by the plow. It then grew downward to one foot and horizontal for eight feet more. The longest tap-root was nine and one half feet.

Individual sour-stock roots differ from each other in manner of growth. A number of trees were examined and the numerous tap-roots went deep in every case. Those trees which had few lateral roots made less growth and produced a much smaller amount of fruit than those which had numerous laterals near the surface. The root-systems of

PLATE 7. WASHINGTON NAVEL ON FLORIDA SOUR-STOCK ROOT. NINE YEARS OLD.

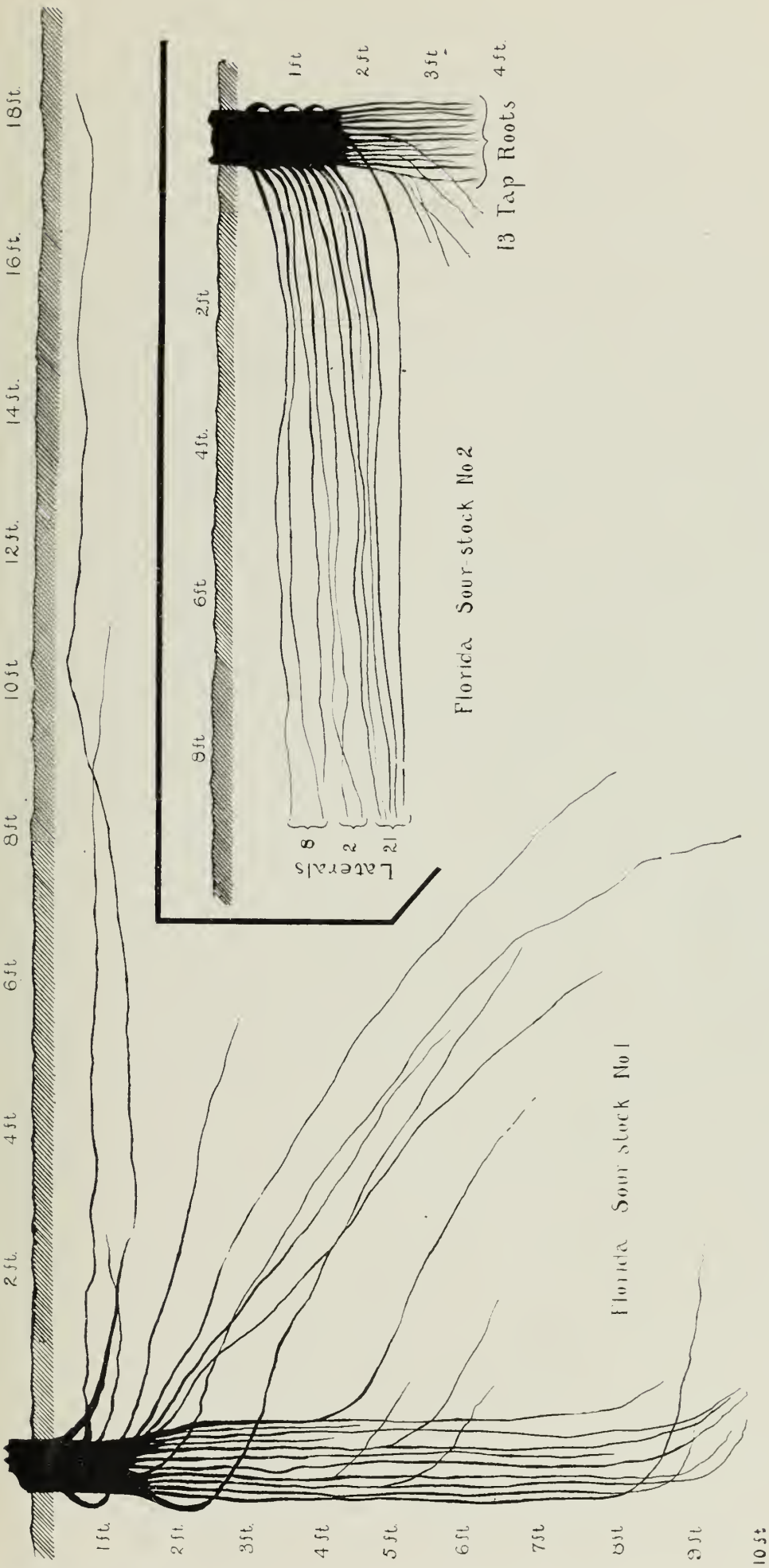


PLATE 8. SHOWING LENGTH OF LATERALS AND DEPTH OF PENETRATION OF FLORIDA SOUR-STOCK.

No. 1. Produced 110 pounds of Navel oranges when 9 years old. Thirteen laterals in half of root; had few fibers.
No. 2. Produced 204 pounds of Navel oranges when 8 years old. Thirty-one laterals in half of root; had many fibers.

two of these Florida sour-stocks at the substation are shown by drawings on plate 8. It is plainly a very strong, healthy, and valuable root-system. The orange tree shown on the left side of the chart bore 110 pounds of oranges when nine years old. The descending roots were traced to nine feet from the surface. The other tree, shown in part at the right side of the chart, bore 204 pounds of oranges when eight years old. The accompanying data shown in the illustration are well worth studying.

There has been some complaint among growers that Navel orange trees budded on sour-stock become more liable to frost than those budded on sweet-seedlings. This is not confirmed by recorded observations. A letter from Grao, Spain, in the United States Consular Reports, says that stocks from the sour-orange raised from seed "are more vigorous, more luxuriant, and of longer duration; besides, they best resist the cold, for which reason they are preferred and chosen for the trunks of trees of tall growth." At the Pomona substation there has not been any noticeable difference in the hardiness of orange trees grown on the two kinds of stock—sweet-orange and Florida sour.

It has been claimed by some growers that sour-stock has an influence on the quality of the orange. Several firms who handle large quantities of all kinds of fruit from both California and Florida were asked if they had discovered any such difference. P. Ruhlman & Co., of New York, wrote under date of July 1, 1901: "We are not able to enlighten you as regards the difference in the eating- and keeping-qualities of oranges grown on sweet- and sour-stock. In our judgment the soil has everything to do with the keeping-quality of oranges. For instance, we have known several orchards whose fruit formerly arrived from Florida in decaying condition, whether it was shipped early or late. Now, by proper fertilizing, and principally the use of potash,* the fruit has changed in character and become of the best keeping-quality (would hold up for a month)."

James S. Watson, president of Porter Bros. & Co., of Chicago, wrote, July 8, 1901: "We consider oranges budded on sour-stock to be of better eating-quality and to have better keeping-qualities than those budded on sweet-stock. That has been our experience, especially in Florida."

The chemical analyses of oranges grown on sweet-stock and on sour-stock, made at Berkeley by the California Experiment Station, and published in previous reports, show such slight variations, easily arising from unavoidable differences in the ripeness of the specimens used, that the theory of the poorer quality of fruit grown on sour-stock can not be justified.

*The soils of Florida, as shown by many analyses, are very deficient in potash.

Conclusions Respecting Stocks.—The reader, examining with care the quite different root-systems shown in the preceding illustrations, and following the observations heretofore given in this paper, will be prepared to form a trustworthy opinion of his own. He will note that the sweet-orange root is a persistent surface-feeder, having almost its entire root-system above a depth of eighteen inches and rising to within eight inches of the surface. This stock, he will observe, produces an abundance of fibrous roots that concentrate near the surface, just beneath the reach of the plow and cultivator, thus making the tree too susceptible to drought.

On the other hand, the root of the sour-orange penetrates to a depth of nine feet or more (see plates 7 and 8), sometimes having numerous laterals near the surface, and sometimes having fewer but more sharply descending laterals. Both a deep root-system and broadly extending laterals, not too near the surface, are essential to the ideal stock. There would seem to be room for some selection among sour-stocks so as to obtain these qualities in the highest possible degree. Though the sour-stock does not appear to bring trees into full bearing as soon as do the sweet-orange and the pomelo stocks, the value of the sour-stock in other directions may compensate for this defect, and it seems probable that in localities where the sweet-stock fails, sour-stock will be used to a greater extent than now.

It has been shown that the pomelo laterals are found at a somewhat greater depth than the laterals of the sweet-orange. The pomelo produces more fibrous roots than do either of the other stocks, and consequently the tree is a ravenous feeder. It is resistant, to a certain extent, to the form of gum disease that attacks the roots of citrus trees. On the whole, the pomelo is deservedly becoming the favorite stock in Southern California. In practice it has succeeded better at the station than has the sour-stock, which seems to lack uniformity of root growth, sometimes having few laterals, in which case the crops are small. The pomelo seedlings have made the best growth in the nursery.

METHODS OF PLANTING ORCHARDS.

The land chosen for the site of an orange grove should be surveyed, and well graded wherever necessary, so that water will flow to every part of the tract from the main pipes or ditches. It ought to be thoroughly worked, at least a foot deep, plowing twice and harrowing well; a subsoiler attachment can be used to loosen the soil several inches below the bottom of the plow-furrows. The orange tree requires a warm, rich, and well-drained soil, which receives the best of cultivation. The water system must be under complete control, so that waste and over-irrigation can be avoided. The soils of the orange sections vary

considerably in respect to the percentage of sand, decomposed granite, limestone, or red oxid of iron which is claimed to give high color to the fruit, but all are suited to irrigation and have a porous, well-drained subsoil.

The Ordinary Transplanting Method.—The almost universal method of moving young orange trees from the nursery is to cut off a large part of the top, leaving short stubs of branches, and even from these the leaves are sometimes stripped. This, of course, is to balance the loss of a large part of the root-system at the time of transplanting, and to lessen evaporation. Twenty or thirty gallons of water are usually given to each tree at the time of planting. If the leaves do not fall after the trees have been planted a short time, but show a disposition to turn yellow, they should be removed.

The Reed System of Transplanting.—Much better results are obtained by the method adopted by Mr. J. H. Reed, of Riverside. According to his method, vigorous trees are selected in the nursery, and are well watered before removal. The longer branches are but slightly cut back, leaving most of the foliage on. The trees are then lifted with large balls of earth, and are taken directly to the plantation, where holes two feet deep and two and a half feet wide have been prepared, into which they are placed, and the earth is well filled-in around each ball, not firmed, but settled with water, so that the trees will stand at the same height as they did at the nursery. No planting should be done unless there is irrigation water available at the time. After the ground has been soaked for several feet on all sides of the newly-set trees, thorough cultivation should follow, as soon as the land is in a proper condition. Under any system of transplanting this is good practice.

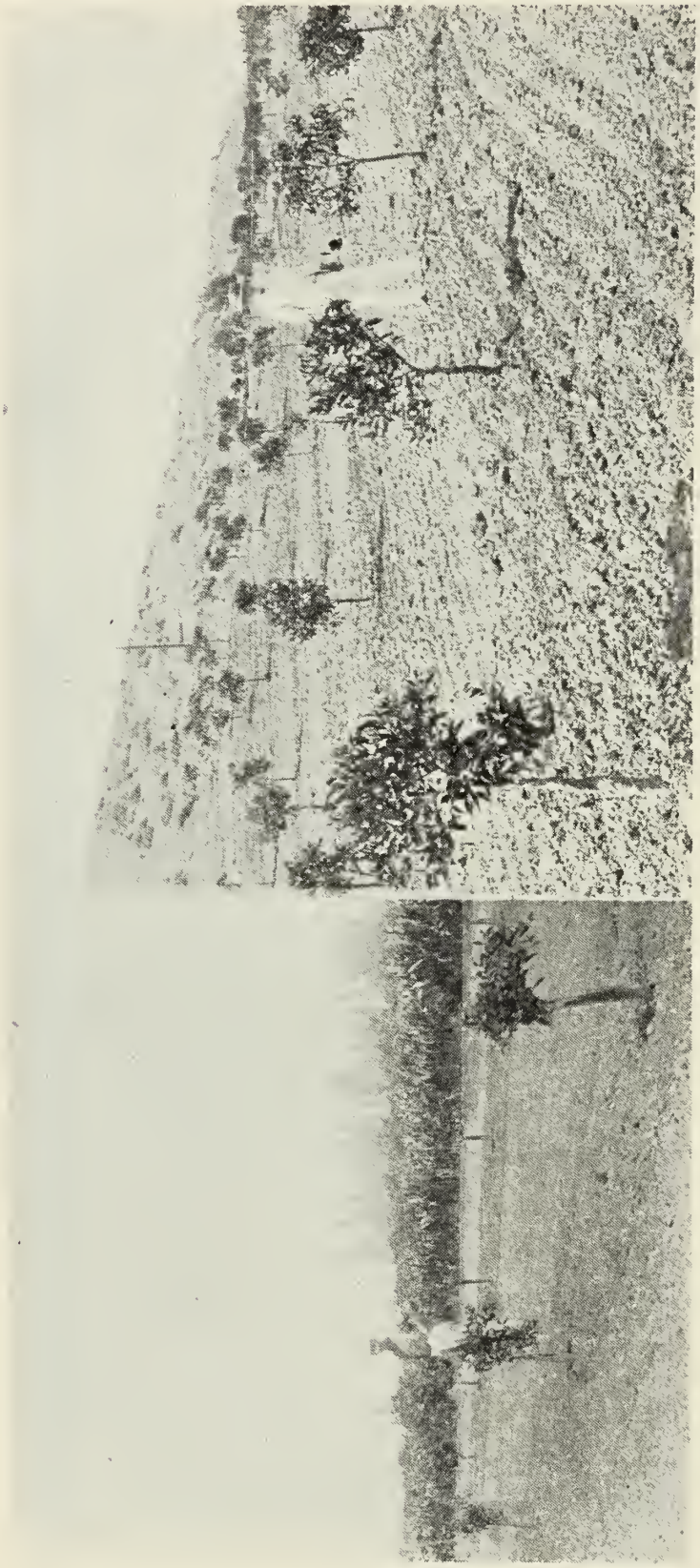
Mr. Reed says further: "A small amount of fertilizer is applied soon after planting, for the young roots to use when they first start out from the balls. A pure bat guano with a high percentage of nitrogen, about three fourths of a pound to the tree, has been found to give the best results; but any commercial fertilizer rich in nitrogen, or animal fertilizer, if placed properly and kept moist, answers well. It is applied in trenches each side of the ball, at right angles with the irrigation furrows, and reaching to them. They may be made by plowing a deep furrow and deepening with a shovel to ten or twelve inches. The material is carefully distributed and slightly mixed with the earth at the bottom of the furrows; the water from the irrigating furrows keeping this always moist, it is available as soon as reached by the rootlets. This also tends to deep rooting. Thorough irrigation should follow planting every twelve or fifteen days during the first summer. The whole space between the rows should be thoroughly and deeply wet—

27 months.
Ten boxes of oranges per acre in the second year.

38 months.
One hundred boxes of oranges per acre in the third year.

PLATE 9. WASHINGTON NAVEL ON SWEET-STOCK, ACCORDING TO THE REED METHOD.

not merely a narrow strip on each side of the rows. I have traced roots that have grown during the first summer over six feet from the tree, and these should be well supplied with moisture at all times."



Ordinary Method. Trees 6 months after planting. The Reed Method. Trees 40 days after planting; less than one per cent required cutting back.

PLATE 10. COMPARATIVE GROWTHS AFTER THE ORDINARY AND THE REED METHODS OF PLANTING.

The advantage claimed for the Reed method is that it retains the top of the tree, and makes use of it immediately. This retention of nearly all the leaves and branches enables trees under proper conditions to

produce a much more vigorous growth than under the ordinary system of severe pruning, when moved from the nursery. The best of care is essential to success in this method. If trees are to receive poor or only ordinary treatment after being set in the orchard, the common method of severe pruning is best. Mr. Reed himself prunes back any trees that show lack of vigor after being transplanted, watered, and fertilized.

The good start given to trees by the Reed method is shown in their size, vigor, and productiveness for an indefinite time, and it is also claimed that a crop of oranges is obtained, without injury to the trees, one year earlier than if they were planted by the usual method. Trees thus planted (on the Reed system) produced over one hundred boxes of oranges on ten acres, the second year from planting, and one box per tree three years from the time of planting. The trees are shown in plate 9. Ten acres of trees five years old produced 2,500 boxes. There was no appreciable injury done the young trees on account of the early bearing, for they continued to make a sturdy growth while maturing the crop of fruit. Trees planted in the usual way one year before, on adjoining land that is similar in character, although receiving good care from the start, are not now as large as those of Mr. Reed, though apparently thrifty.

This method of transferring trees to the orchard and securing their rapid establishment there, is based upon intelligent selection in the nursery and very careful attention to details after transplanting. Mr. Reed does not claim that he originated the method, but it has not been observed except in his orchard, which furnishes an excellent illustration of its value under proper conditions. The photographs given on plate 10 show the contrasts between an orchard planted by ordinary cutting-back methods and one planted on the Reed system.

The "Post-hole" Method.—There is another new system of planting orange trees that is being used at the Southern California substation, but practical work has not been carried on long enough to demonstrate its real value. In this method, holes are bored with a post-hole auger in the bottoms of the regular-sized tree-holes, to a depth of five or six feet. They are filled up to the point at which the bottom of the tree rests with peat or well-prepared compost, thus affording good drainage. The roots, it is thought, will follow this rich soil downward, and thus establish a deeper root-system. In selecting a soil for any "post-hole" planting, it is very important to remember that young orange roots are easily injured by alkali or strong fertilizers, and care should be taken to avoid an injurious compost or one that prevents free drainage.

WORKING-OVER OLD ORCHARDS.

In every fruit district, the introduction of inferior varieties necessarily causes much loss to growers, as it is expensive to replant or to work-over old orchards. This is the price that horticulturists willingly pay for new and improved varieties. The orange-growers of Southern California have experimented with almost every known variety, and have been compelled to abandon a number that once were popular. The heaviest loss incurred was because of the inferior Australian Navel which preceded the Washington Navel and sufficiently resembles it in growth to have been sold in numbers of cases for that far better variety.

PLATE 11. WORKING-OVER OLD ORCHARDS. Old Mediterranean Sweet re-budded to Washington Navel. Tops left on during first winter as protection against frost.

In recent years many trees of Australian Navel, Mediterranean Sweet, and seedlings have been re-budded to the Washington Navel and its improved types.

While it is easy to perform the operation of budding, it requires special knowledge and skill to get the new tree-top rightly started and through the first season. Even an old orange tree will take buds in the main branches or trunk, and will produce a luxuriant growth from the buds the first year, if properly managed. But if such trees lose their tops after the first summer's growth, they are usually worthless, or are not profitable for years. In such cases it is better to take out the trees and plant young budded trees from the nursery.

The Method of Re-budding Trees.—Old Mediterranean Sweets are among the most difficult of citrus trees to re-bud, and very poor results

will be obtained if they are handled by ordinary methods. Mr. E. L. Koethen and Mr. O. D. Wilheit, of Riverside, have been very successful in budding-over all kinds of old citrus trees, including Mediterranean Sweets. They trim out all branches that are not used to insert buds into, and then thin out the remaining branches above where the buds are inserted. This is done early in the spring, and at the time of budding. The removal of surplus limbs directs the entire flow of sap into the branches containing the buds, which results in their healing-over quickly and becoming well united. Upon the removal of the tops of the trees, the buds start at once. All saw cuts are covered with some material that will exclude the air, usually grafting wax, though Mr. Koethen has experimented with thin putty, and finds it much cheaper, more durable, and not injurious to the tree. After the tops are removed, the trees should be whitewashed to prevent sunburn.

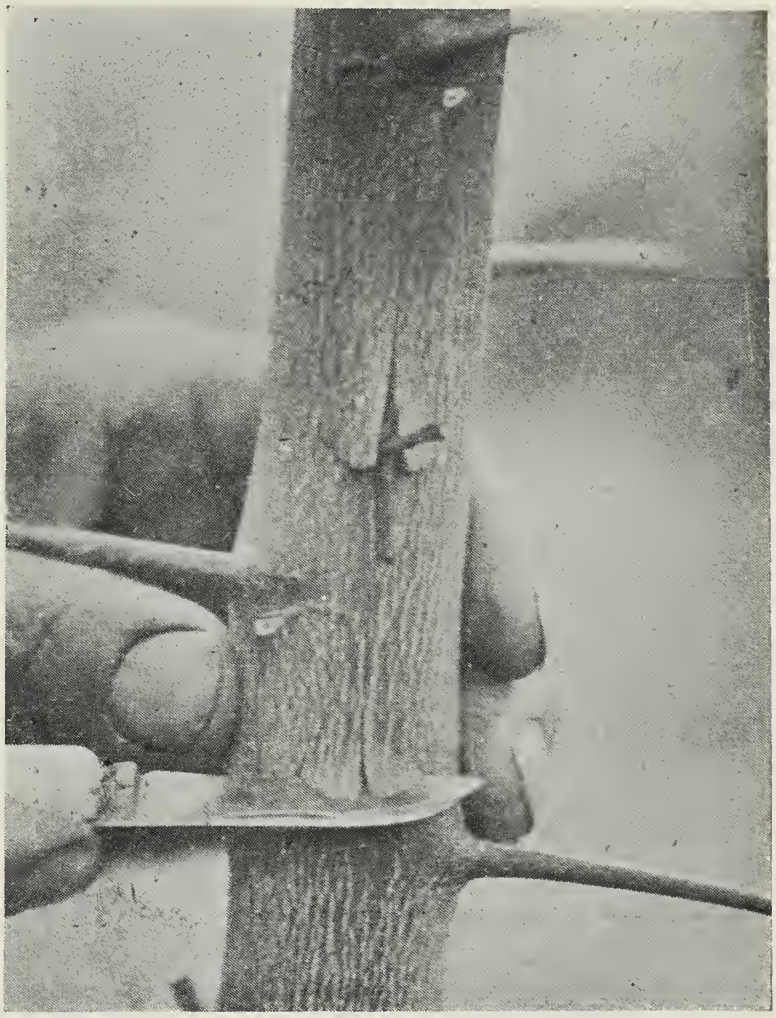


PLATE 12. Working-Over Old Orchards.
Placing the bud.

Value of "Cured" Buds.—The best success comes from using "cured" buds; these are buds that have been cut from the tree and kept in damp sand or moss for a few weeks before using. When treated in this way they become tougher, and when inserted into a tree that has freely-flowing sap they absorb it more readily. When buds are well cured, and not allowed to become either too wet or too dry, they are not easily injured in handling. The delicate germ is very brittle when the scion is first cut from the tree, and the slightest touch will sometimes destroy it.

Placing the Bud.—The incision which is to receive the bud is made by running the knife down the side of the branch or trunk of the tree. The cross-cut is made at the lower end of the incision instead of at the top, as is the usual method, and slants upward. By giving the knife a

slight twist before removing it from the last cut, the two corners are turned out, which, with the upward slant, forms an opening, into which the bud slips easily. Narrow strips of waxed cloth are then wrapped around the limb, completely covering the inserted bud and the incisions. The insertion of the buds from below gives better protection from rain and dew. (See plate 12.)

When to Remove the Bands.—These waxed bands are allowed to remain on the buds for from four to six weeks, according to the weather. During such a season as the spring of 1901, which was cool and damp, citrus trees make very little growth. Under these circumstances the waxed bands should remain a longer time. The bands were removed

1 2 3

PLATE 13. WORKING-OVER OLD ORCHARDS. Sixteen-year-old seedling, budded and topped. 1. Before beheading. 2. After beheading. 3. New growth three months after beheading.

from the buds after four weeks (the usual period) in a number of cases in the Pomona Valley in 1901, and they generally died, but in the same year when the bands were allowed to remain on the buds for six weeks the result was satisfactory.

Removal of the Tops.—There are three usual methods of removing the tops after budding: (1) the removal of the entire top at the time of taking the bands from the buds; (2) the removal of all branches but one, which is left to draw sap; and (3) the girdling of the limbs above the buds while still retaining the entire top for one year.

When the first method (illustrated in plate 13, and also in plate 14)

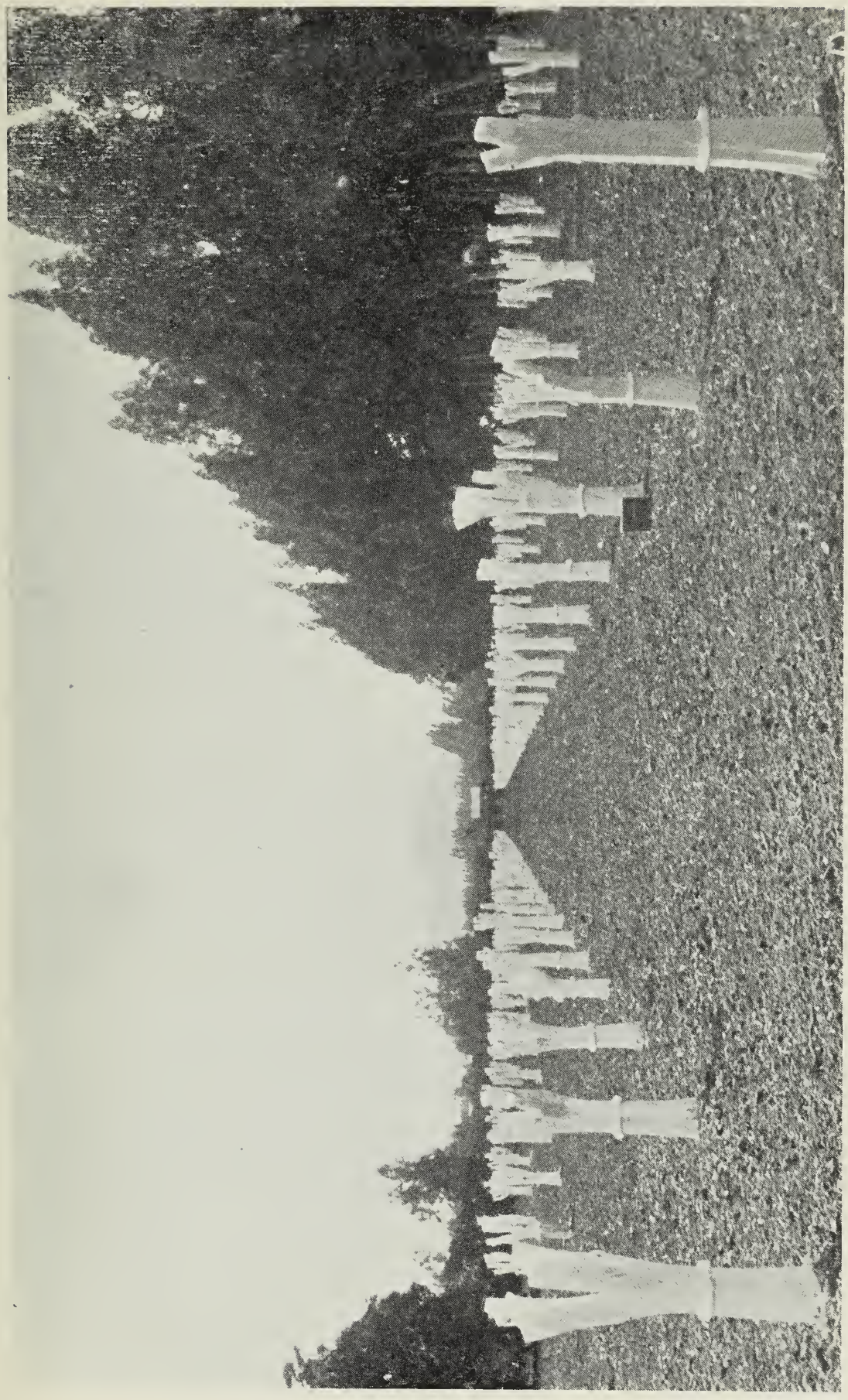


PLATE 14. Working-Over Old Orchards. Appearance of orchard on removal of entire top at time of taking bands from the buds.

is practiced and proper protection is given to the buds and young top during the first year, better results seem to be obtained than by any other way. The new top receives the entire nourishment afforded by the tree; with frequent pinching-back of the new branches, the wood can be hardened and better matured before winter, and the leaves become thick and heavy, affording much frost-protection. This is shown in plate 15. Both trees were budded in May; No. 1 was topped in June at the time of removing the bands; No. 2 was topped in July, one month after bands were removed. The photographs were taken a year later, and are typical of five-acre blocks. But when this method is

1 2

PLATE 15. WORKING-OVER OLD ORCHARDS. 1. Topped when bands were removed. 2. Topped one month after bands were removed. Photographs taken one year later.

employed in frosty sections, the tops must be protected still further during the first winter. The young growth will be killed when the thermometer registers from 25° to 27° Fahr., and if the tops are killed back to the old wood, the trees will seldom or never become useful, often failing even to send out suckers. An illustration of this frost effect is shown in plate 16.

The value of protection to the young top during the first winter was shown by a lemon orchard, in a frosty location, that was budded-over to Washington Navel oranges. When the tops were removed, the growth from the buds was wrapped with palm leaves during the first winter; eighteen months after the trees were budded, they were past all danger from frost, and were large enough to produce a box of oranges per tree. (See plate 17.)

PLATE 16. Working-Over Old Orchards. Frost effect on unprotected young growth.

PLATE 17. Working-Over Old Orchards. Lemon stock 18 months after being budded to orange; in a frosty location, but protected by wrapping with palm leaves.

Seedling orange trees that were budded-over when sixteen years old, and were protected by nailing palm leaves to the trunks and by wrapping the palm leaves around the new tops, produced an average of eight boxes per tree during the first five years after they were so budded.

The second practice of *leaving a side branch on the tree* to "draw sap" is a safe method, and will sometimes save a tree if the buds fail to grow; but when budding is skillfully done there is no need of leaving side branches. (See plate 18.)

PLATE 18. Working-Over Old Orchards. Pomelo budded to orange; leaving side branch to keep up circulation.

Girdling the branches above the buds after they have healed over and the bands have been removed, while leaving the tops on until after the first winter, is not practiced widely, but has some ardent advocates. The top when thus left continues to draw enough sap to keep alive, and to ripen a crop of early and poor fruit. The removal of such a top after the buds have made one year's growth is sometimes difficult without injuring the new head. The chief advantage for this method is that the old top forms a covering for the new head, obviating the necessity of wrapping it for protection against frost. Trees handled in this way (see plate 19) have made a better record than adjoining trees that had the tops cut off at the time when the bands were removed from the buds and were left unprotected during the first winter. (See plate 20.)

When the leaves of fan palms are used, the stems are tied around the trunks of the trees and the broad leaves are fastened around the tops. After spring frosts are over, the palm leaves are removed. Sometimes the palm stems are nailed to the trunks of the orange trees, which is more convenient than tying. Though not a praiseworthy method, yet this does not seem to injure the trees.

The old-time method of cutting off the entire top of a tree so as to bud upon suckers is now considered a poor way, as a year of time is thereby lost.

PLATE 19. WORKING-OVER OLD ORCHARDS. Top removed when buds have a year's growth; protection given thus against frost.

PLATE 20. WORKING-OVER OLD ORCHARDS. Top removed at time of budding; no protection made against frost during first month.

PRUNING AND SHAPING TREES.

The tendency of young trees of Washington Navel and some other varieties to assume a drooping habit when making a vigorous growth is due to the fact that the soft shoots are unable to support the weight of the large, heavy leaves. Mr. Reed writes: "It can not be expected that the soft, succulent shoots will grow upright when they are weighed down with the great fat leaves that vigorous young Navel trees always produce, but if they are pinched back they will soon begin to straighten up. If this method is followed, a Washington Navel tree can be made symmetrical and upright. I make it a point to visit every one of my young trees several times during the season and pinch back shoots."

Even trees that have been long in bearing will be benefited by pinching back every branch that takes too vigorous an upward growth. This pinching process is especially necessary with trees from one to five years old.

Pruning Bearing Trees.—The advantage of an upright tree over a drooping one is considerable when it becomes loaded with fruit. The crop is borne with less breakage of limbs, and not so much fruit is injured with the wind. After they are in full bearing, there seems to be no pruning that will promote the health of the trees or improve the crop, other than cutting out limbs that project abruptly from the side, or those that make a sudden skyward growth, and the constant trimming out of dead or stunted wood that is found on the inside of the trees.

If too close, the branches of a tree should be thinned out from the inside until the sunlight has had free access. This does not make any noticeable difference in the appearance of the tree, but makes it bear fruit on the inside. Such fruit is safe from sunburn and frost, and packs as "fancy" grade. By early attention to pruning, the trees need never be allowed to grow too close in the center.

Renewal of Tops.—There are some groves of old orange trees that do not respond to the best treatment that the owners can give them. Under such circumstances, the most effective way to stimulate new life and vigor is sometimes to remove the entire top, leaving enough of each of the main limbs to distribute equally the suckers that will afterward make the new top of the tree. If the tops are only thinned out and but partially cut back, there will be a proportionate amount of feeble growth and a corresponding lack of productiveness. An old orange tree will rapidly produce a new top, even when cut back to a mere stump. It is soon in a condition to bear again at its full capacity. When the roots are healthy and the soil is properly cultivated and fertilized, the orange

tree appears able to produce several generations of tops on one stock. But it will generally be found that the trouble with old, non-productive trees lies in the root-system, or in the management of soil, or in both. Thorough investigation of roots and soil should be made before any severe cutting or pruning of the top is resorted to.

Except as noted in preceding paragraphs, all trees should be trained low for protection against frost, heat, and wind, and to aid the gathering of fruit. Heavily-laden branches are generally propped to prevent breaking down, as the loss from dropping and splitting is so great that the trees cannot be safely lightened by thinning of fruit when small.

CULTIVATION AND IRRIGATION.

During the past seven years the substation grove has been plowed deeply at least twice north and south one year, and twice east and west the next. Every year the plow turns up masses of fibrous roots that grow just below the reach of the cultivator teeth, in the strip of land between the trees in the rows running in the direction of the last plowing. These roots grow from five to twelve inches below the surface during the winter and spring when the soil is kept moist by rains. Their presence shows the upward tendency of the feeding roots of orange trees when left to grow naturally under favorable conditions.

The extent to which the root-systems of orange trees can be influenced by orchard treatment seems to be very limited.

The deep-rooting tendency of the sour-orange (plate 8) is observable in both light and heavy soils, while the roots of the sweet-orange, and in a lesser degree those of the pomelo (plates 6 and 7), grow near the surface in all kinds of soil during the seasons of their most rapid growth, and the only way in which they can be forced to a lower depth is to plow deeply and apply irrigation water as low as practicable. As orchardists can not with present facilities afford to plow deeper than ten or twelve inches, the fibrous roots will mostly be found just below that depth. Even after trees become old and well established, their fibrous roots continually seek the surface soil, unless deep plowing and deep irrigation are persistently practiced. One orchard near Pomona, which has been plowed deeply from the time it was planted and irrigated in deep furrows, bore four and a half boxes of fruit per tree at the age of eleven years. An adjoining orchard that was never plowed, but was cultivated frequently and irrigated in furrows made with a "bull-tongue" attachment, produced but three and a half boxes of poorer oranges at the same age. The former orchard is budded on sour-stock, which, as heretofore shown, roots deeply, and it received a liberal amount of fertilizers; while the latter orchard is budded on the shallow-rooting

sweet-stock, and received but a moderate amount of fertilizers. The more productive of these two orchards evidently has the better root-system; it has also been plowed deeply and irrigated in deep furrows—therefore, it never shows the need of water before the regular irrigation date comes around. On the other hand, the less productive orchard, which is on surface-rooting stock and has received much shallower culture and watering, shows signs of drought before each irrigation date. In the case of orchards on the same stock, the value of deep plowing and deep irrigation is also very marked.

The So-Called "Hardpan."—The orange tree is a native of tropical forests, where it obtains warm soil and abundant moisture within easy reach. Its successful culture in the countries like California, which lack summer rains and moisture-laden atmosphere, is necessarily to some degree artificial and a notable triumph of modern horticulture. In order to achieve the highest results, it becomes more and more essential that the grower shall keep the soil in the most perfect condition, shall apply all needed water and plant-food in sufficient but not in excessive amounts, and shall pay especial attention to keeping the feeding roots as low as practicable and to preventing the formation of what is called "hardpan," but is only the well-known "plow-sole," aggravated by shallow irrigation.

"Hardpan," some growers say, appears now where it was never before known. The fibrous roots of orange trees run along its surface, and thus are subject to every vicissitude. It often happens that what orchardists call "hardpan" is only the firm layer of soil caused by uniform cultivation, or plowing, whether deep or shallow. The depth to which soil is stirred should vary from year to year; eight inches, twelve inches, ten inches, fourteen inches, and then eight inches again, would put an end to much of the present outcry against "hardpan." Cultivator teeth should also be kept sharp and should be "set down" to various depths so as to prevent the formation of "plow-sole" of any description, and to assist in breaking up that which former neglect has caused.

Very few orange groves have been planted upon true "hardpan," and if so planted have seldom succeeded. Only a few trees, such as our native oaks, are capable of thrusting roots through the iron-like layer of natural subsoil that is properly termed "hardpan." When found to exist, it should be deemed sufficient to debar citrus culture, unless so thin that, by boring or blasting, the root-system can be established in good soil below the "hardpan," or when it is so constituted that when kept irrigated the roots will penetrate it.

An instance of the latter occurred at Riverside, where Mr. Reed planted a few trees on a terrace bordering on an arroyo, and found what

was reported as true "hardpan" near the surface. The trees received "an abundance of water over the whole area for a year," and it was then found that the roots had penetrated it to a considerable distance.

The term "irrigation hardpan" is quite generally used in the orange-growing district to describe the condition of some small areas in orchards where irrigation and subsequent culture have been careless, or where sufficient attention has not been paid to the difference of treatment required by lighter and heavier soils.

Of course very sandy soils can be handled sooner after irrigation than can heavier soils, and when a sandy piece of land containing areas of heavy soil is cultivated as soon after irrigation as the sandiest part will permit, trouble may be expected with the so-called "irrigation hardpan," by the puddling of the subsoil, partly directly by the plow, partly by the soaking-in of clay-water.

Value of Proper Cultivation.—It is usual for orchardists to put in a subsoil plow to help in breaking up the heavy spots of what is called "irrigation hardpan." But this difficulty can easily be overcome without using a subsoil plow, as was shown by the experience of Mr. W. J. Cox, of Glendora, Los Angeles County, who found that "irrigation hardpan" was forming in a part of his orange grove. He irrigated a few trees that were within reach of the domestic water-supply, and followed this up at the proper time with thorough cultivation. After each irrigation he cultivated a little deeper. As a result of deep irrigation and cultivation, the soil took in water as readily as ever and the trees regained their vigorous appearance. He simply used a chisel-tooth cultivator and plenty of water.

A somewhat different case was that of Mrs. McKenzie, of Riverside, whose orange grove failed to be profitable, though apparently well irrigated. This orchard had been cultivated to the same depth until a hard, clay "plow-sole" had been formed. The stratum of hard subsoil was several inches thick and contained a number of large surface roots. She wrote to the California Experiment Station, sending samples of soil for examination. It was found that the plow-sole prevented the irrigation water from reaching the deeper roots, and she was advised to plow the entire orchard, roots and all, as deep as the plow would go. This was done, much to the alarm of many growers, and great numbers of orange roots of all sizes were turned to the surface. Following further advice, she irrigated and cultivated the ground deeply, and the following season she harvested the largest crop ever taken from this grove.

The Glendora grove, to which allusion has been made, had had deep cultivation from the beginning, and the roots were mainly below the so-called hardpan. The McKenzie grove had many roots in the hard "plow-sole," so that the only remedy was to destroy these useless roots and force the growth of new and deeper ones, at the same time giving

the irrigation water a chance to penetrate. This rather drastic root-pruning was necessary, and if the Glendora grove had been cultivated to a uniform depth a few more seasons, deeper plowing and the destruction of the surface roots would have become inevitable there also. The breaking-up of all hard layers of soil caused by improper cultivation or careless use of water is of the first importance to the health and profit of an orchard.

Reckless Deep Cultivation.—After Mrs. McKenzie's experiment at Riverside, previously mentioned, subsoilers of different forms were used, and the idea soon became common among growers that the deeper a plow could be run, the better would be the results that would follow. The injurious results of such practice can not be estimated without careful study of the root-systems of orange trees on various stocks and soils. A number of bearing citrus groves were so much injured by the reckless use of subsoil plows that the leaves of the trees actually wilted down immediately after the operation. In these cases, the sharp-cutting plow was run close to and on all sides of the trees. When trees over ten years of age, which have been subjected to uniform shallow plowing and irrigation, are submitted to such treatment, they probably lose at one blow not less than seventy-five per cent of their active roots. The shock is such that it would take several years of careful treatment to restore the trees.

Practical Notes on Deep Cultivation and Irrigation.—It is almost always more economical to use a subsoiler or plow where "irrigation hardpan" has been formed than it is to use the large amount of water necessary to soften it; but according to the best practice the deepening of cultivation should be gradual, and the implement should never run deeper than fifteen inches. One must remember that the really serious loss in sudden deep cultivation comes from the destruction of thousands of fibrous roots that grow from the hundreds of laterals branching from the large main roots.

If a plow is run to a depth of one foot, in three furrows, between the rows, and water percolates slowly for a long time through these furrows, no need can arise for a subsoiler. "Irrigation hardpan" within reach of the plow simply shows, as has been said, that too shallow and too uniform cultivation has been practiced. In that case the entire surface should be thoroughly broken up, and irrigation in deep furrows after this will restore the proper conditions.

Experience also shows that when the water is slowly run in deep furrows for a long time and the greater part of the surface is kept dry and is deeply cultivated, better results are obtained than when the basin or block method, or even the shallow-furrow plan, is used, even though they are followed by deep cultivation. When the water is applied

below the first foot of soil, and the soil above is kept comparatively dry, there is nothing to attract the roots to the surface; and when the water is thus applied, a team can be driven along the dry strips of land between the furrows, and with a harrow or other appliance the dry soil can be dragged into the wet furrows, to lessen the evaporation, immediately after the irrigation water is turned off. By any other system, it is absolutely necessary to wait at least twelve hours, and sometimes much longer, before a team can be driven over the ground. Then, too, when a soil irrigated by these more wasteful methods has been cultivated, it is still moist near the top, and is soon filled with a mass of new roots so close to the surface that they must be destroyed.

Waste from Evaporation of Water.—Water applied to the soil sinks and spreads. Some of it is being taken up by the still dry soil underneath and at the sides long after the last drop is visible. Some of it, too, is being drawn back to the surface, and thence evaporated into the warm air. Irrigation after sundown has some distinct advantages, if the water can be handled. Sub-irrigation upon soils adapted to its use is the ideal system of applying water, and greatly lessens waste. Orange roots will not enter a pipe-line unless it is full of water all the time. If the pipe is on a grade and open at bottom and top so that air passes through it, there will never be trouble from orange roots. Valves, once thought necessary, are not now used. The high cost of the present sub-irrigation systems places them beyond the reach of most orange-growers.

Spread of Water from Deep Furrows.—The accompanying diagrams (plate 21) show the extent to which water from fairly deep furrows penetrates the sandy soil and the heavy loam of the substation. A moment's study of them will convince any one that the only way in which to lessen waste in surface irrigation is to let the water flow slowly through as deep and narrow furrows as practicable, thus making a larger cross-section of wet soil, even narrower at the surface than in the chart, and checking the evaporation by filling the furrow with dry earth and by cultivation at the earliest moment.

Examining these suggestive diagrams of soil-saturation, let us first call attention to the three showing the spread and descent of water on the heavier soil. Here it has spread much more slowly and to a less extent than in the case of the adjacent sandy land. Even after two days' run of water (of twelve hours each) and seventy-two hours further delay (see No. 3), the total sectional area of saturation is hardly more than half as great, covering about sixteen square feet, as against about thirty square feet on the lighter, more porous soil (see No. 6). A still deeper and narrower water channel is highly desirable on this heavier soil. Instead of eight inches, it might well be sixteen or eighteen, which

would make the cross-section, No. 3, nearly a foot deeper, and narrower on the surface.

The cross-sections on the sandy soil show that the eight-inch furrow is practically sufficient to carry the water well down into the soil. A deeper, narrower channel even here will result in economy in the use of

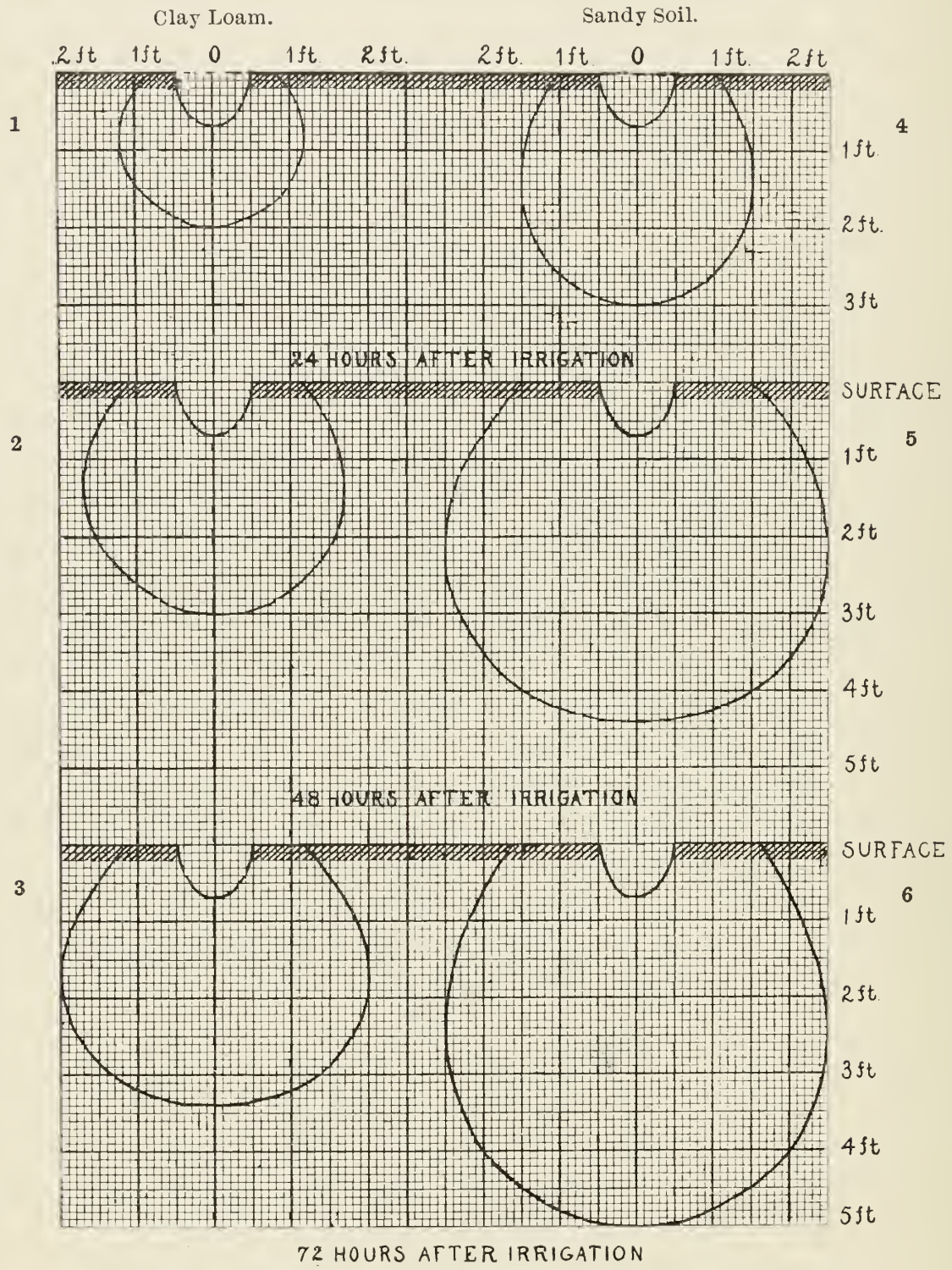


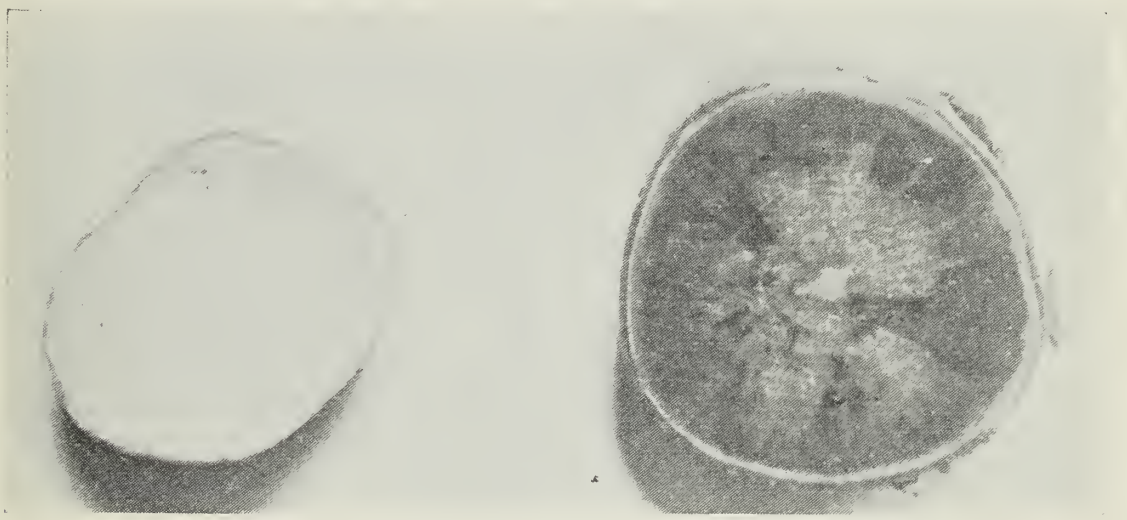
PLATE 21. Percolation Experiments. Spread of Water from Deep Furrows in Heavy and Light Soils.

water, a smaller flow producing as large an area of saturation as that shown in diagram 6, with less surface. These two sets of illustrations of the results of irrigation in furrows on different soils, under conditions otherwise practically identical, explain and enforce the entire argument respecting deep irrigation set forth in this bulletin, and long and earnestly recommended by Professor Hilgard.

NOTES ON DISEASES OF THE ORANGE.

Three diseases of the orange tree are widely known in California. First in importance come two kinds of "gummosis," or "gum disease," that which attacks roots and trunks just above the surface of the ground, and, second, that which is called "scaly bark" gum disease. The former has existed in Southern California since 1875. It makes its appearance where the ground has been allowed to remain wet close to the trees for long periods. E. W. Holmes, of Riverside, says that he has seen fifteen per cent of a seedling orange orchard become affected after heavy applications of nitrogenous manures followed by irrigation close to the trees during hot weather. All the affected parts should be cut out so as to remove every trace of diseased tissue. In some cases this requires repeated cuttings and the use of an antiseptic wash.

The "scaly bark" gum disease is the most prevalent form in Southern California. It attacks the trunk of the tree, and also some of the



a *b*

PLATE 22. GUM DISEASE OF THE ORANGE WOOD.
a. No disease. *b*. Darkening of wood by disease.

branches. If not checked at once it will kill the tree. The new bark is unhealthy, and the disease soon penetrates to the center of the limb or the trunk of the tree. (See *b*, plate 22.)

Antiseptic Washes for Gummosis.—The treatment for both forms of gum disease is the same. Use one part of crude carbolic acid to four parts of water. The Florida Experiment Station uses a wash of lime, crude carbolic acid, and salt. Slack one peck of lime in two gallons of water, and add, of crude carbolic acid four ounces, and of salt three pounds. If too thick, add a little more water.

In cases of the root form of gummosis, the soil should not be thrown back upon the roots after cutting out the diseased tissue, until the wounds begin to heal. It is necessary, however, to shade the roots from

the sun. The diseased wood should be burned. Removal of the entire tree is often wiser than trying to cure the disease.

Value of Sour-Orange and Pomelo Stocks.—The "scaly bark" form of gum disease has not been observed in California on the Florida sour-orange stocks. Such trees, budded to Navel oranges two feet or more from the ground, are growing near the substation. Some of them have diseased trunks and branches, but in no case has the disease been found extending down to the sour-stock. Evidently there would be no advantage in using this resistant stock in low-budded nursery trees, but sour-stocks might be planted in the orchard and allowed to form the main branches of the future tree. Then should the "scaly bark" make its appearance, a few branches might be destroyed, but the trunk would remain sound. Since the sour-stock has not given universal satisfaction in Southern California, the pomelo, which seems but little less resistant to "scaly bark" than is the sour-orange, and is a more universally vigorous grower, may be used. The sweet-orange stock is the poorest of the three.

The "Die-Back" Trouble.—The third serious trouble is exanthema, or "die-back." This name is given to a weakness affecting orange, lemon, and other orchard trees. There are several especially bad cases in the San Gabriel Valley, where solid blocks of citrus trees are now utterly worthless. Trees seven years old and in a frostless location have not attained a height of over four feet, in some instances, and bear little or no fruit, while adjoining trees of the same age and seemingly under similar conditions are of large size and bear heavy crops.

Orange trees affected with "die-back" make an apparently healthy growth in the spring and early summer, but the young shoots soon turn yellow, the leaves drop off and the twigs die back to the older wood, from which a brown granular substance exudes. In a season or two, this older wood also dies. Adventitious buds keep developing at the axils of the leaves, until at the end of the season there are small knots, where there should be healthy lateral branches. (See plate 23.) Experiments with Bordeaux mixture and carbonate of copper have been made in a badly affected grove near Pomona. The work so far has shown no appreciable results, but it has not yet been carried through one season.

[In almost all cases of "die-back," examination has shown some fault in the subsoil, which puts the roots under stress. Such fault may be an underlying hardpan or impervious clay, pure and simple; or it may be excessive wetness or dryness of the substrata surrounding the deeper roots; or the rise of bottom water from below, as in cases of over-irrigation. The true "die-back" is not properly a disease, but simply the manifestation of the distress felt by the root-system underground.

The first thing needful is to dig down and examine the roots, and then to relieve whatever fault may be found, if possible; which may not always be the case. Sometimes an appearance similar to the "die-back" is caused by the roots encountering a marly stratum, which is apt to stunt the growth of the tree, causing it to put out a multitude of small, thin branches, and sometimes causing the tips to die off. For this form of the trouble there is no permanent remedy; the trees should

PLATE 23. "DIE-BACK" OF ORANGE LIMBS.

never have been planted in such ground, any more than in such as has shallow-lying hardpan or clay. (E. W. H.)]

["*Mottled Leaf.*"—Closely related in its causes to the "die-back," and sometimes accompanying it, is the "mottled leaf" trouble. It may be properly called "partial chlorosis" of the leaves, and on the basis of that designation it has been attempted to treat it like the corresponding human ailment, with iron tonics and fertilizers. But in every case that I have closely examined, and in most of those reported to me by others who have made such examinations at my suggestion, the cause

was not lack of nourishment that could be remedied by such means, but simply an improper condition of the root-system, especially of the deeper roots. When a thriftily growing tree suddenly stops and begins to show mottled leaves, it is clearly not because of lack of nourishment in the soil, but because some of the physical requirements of the tree's well-being have ceased to be satisfied. In such case fertilization can afford but temporary relief, if any.

The commonest cause of mottled leaf is a layer of dry gravel or sand reached by the tap-roots, throwing them out of healthy action. Of course the same effect may be expected from the exhaustion of the usual supply of moisture in the substrata, which has not been made up for by the comparatively scanty irrigation permitted by the diminished water-supply during the past three years. The cause of the present great prevalence of mottled or yellow leaf in the citrus orchards is probably a parallel to the wholesale dying-out of vineyards in the Santa Clara Valley, regarding which a special bulletin (No. 134) was issued by this Station some months ago.

Quite probably, however, other unfavorable conditions affecting the roots, such as alkali, marl, or a hardpan layer, may in many cases produce this effect. In any case, the cause should be sought for at the roots before deciding upon possible remedies. (E. W. H.)]

Difficulty of Replacing Trees.—It is difficult to install new trees in an orchard when the surrounding trees are large. In fact, it is necessary to dig very large holes and fill them with rich earth. Such trees should be given extra irrigation and additional fertilizers, besides what is regularly given to the older trees. This should not be applied merely to the space around the newly-set trees, but also to the adjoining older trees, as it is needful to furnish enough food and water for all the roots that fill the surrounding soil.

All orchardists find trouble in filling gaps where trees have died or become diseased, but the difficulties are more marked in the case of citrus fruits than with the deeper-rooting deciduous species. A selection of especially healthy specimens from the nursery will help. Then, as noted, the best of culture and all the fertilizers that can be assimilated are needed. Lastly, the judicious root-pruning of large adjacent trees may assist those newly planted.

CALIFORNIA ORANGE AND LEMON STANDARDS.

Citrus-fruit culture includes much that can find no place in so brief a bulletin, but some of the more pressing and practical problems have been discussed. The interesting topic of wind-breaks and hedges for protection against frost and storms has not been taken up, nor has the group of questions relating to the handling and marketing of crops.

But there is often an inquiry made respecting the official scale used

by judges of citrus fruits at fairs and other competitions. A standard scale of points is that adopted by the Los Angeles Chamber of Commerce in 1894 and the following year by the Southern California Fruit Exchange. It seems well balanced, comprehensive, and practical. At the present time it is the most widely used official scale in California.

The following rules have been adopted by the executive committee of the Los Angeles Chamber of Commerce in reference to the judging of citrus fruits:

No person shall be allowed to serve as judge in any class in which he is an exhibitor.

Any exhibitor who addresses a judge while the latter is in discharge of his duty, will be debarred from competition.

A majority of the judges present shall constitute a quorum for decision in any class.

Preliminary Classification.—Season: Early, from December to April; middle, February to July; late, June to December.

Size: Large; medium; small.

(The managing committee from each competing state or section is to nominate varieties to any or all of the above classes, with months, and, when practicable, days, for tests of its own fruit. Fruit to be judged by standards of its class. So far as practicable, no committee is to judge fruit of more than one size, as per above classification.)

ORANGE SCALE TO BE USED.

Divisions of scale: Size, form, color, weight, peel, fiber, grain, seed, taste; to be considered in order named. Credits to be units and tenths thereof, to be expressed decimally; possible total to equal 100.

1. *Size.* Possible credits, 10.

Standards:

Large,	126's,	$3\frac{1}{4}$	inches	in	diameter.
Medium,	176's,	$2\frac{15}{16}$	"	"	"
Small,	250's,	$2\frac{7}{16}$	"	"	"
Tangerines, etc.,		$2\frac{1}{8}$	"	"	"

One unit discount for each $\frac{1}{8}$ inch deficiency or excess in any size.

2. *Form.* Possible credits, 5.

Standards: Round, oval, ovate, pyriform.

Discount for lack of symmetry and for form blemishes. Navel marks not to be discounted, except when of abnormal size or bad form.

3. *Color.* Possible credits, 19, divided as follows: Bloom, 2; peel, 10; flesh, 7.

Standards: Bloom to be perceptible, and to be discounted according to degree of deficiency or of injury thereto; peel to be of rich, deep

orange color, in natural condition, and to be discounted according to degree of deviation therefrom, one or more points; rust, scale, and smut to be discounted five to ten points, and fruit that gives visible evidence of having been cleaned of the same to be subject to equal penalty; also peel that has been rubbed or "polished," giving a gloss at the expense of breaking or pressing the oil-cells, to suffer same discount. Flesh to be rich, clear, and uniform, in any of the shades common to fine fruit. (Omit consideration of "flesh color" until after concluding division 5, "peel.")

4. *Weight.* Possible credits, 10.

Standards: Specific gravity, 1, with buoyancy of $\frac{3}{4}$ oz. allowed to "large" fruit, $\frac{1}{2}$ oz. to "medium," and $\frac{1}{4}$ oz. to "small," all without discount.

One point to be discounted for first half-ounce of buoyancy in excess of allowance, and thereafter two points for each additional half-ounce. (*Note.*—Buoyancy may be easily determined by clasping weights to the fruits with light rubber bands, and then placing in water.)

5. *Peel.* Possible credits, 10, divided as follows: Finish, 3; protective quality, 7.

Standards: Of finish, smoothness and uniformity of surface, and pleasant touch; of protective quality, firm and elastic texture, abundant, compact, and unbroken oil-cells; and $\frac{1}{8}$ to $\frac{3}{16}$ inch thickness.

Discount one half point for first $\frac{1}{32}$ inch above maximum or below minimum, and two points for second $\frac{1}{32}$ inch, provided that to long-picked and fully-cured oranges the minimum shall be lowered to $\frac{3}{32}$ inch; and that to fresh-picked and to slightly-cured "large" fruit the maximum shall be raised to $\frac{1}{4}$ inch.

Breaking of oil-cells, breaking of peel and abrasions of same to be subject to one to ten discounts, according to degree.

(Here consider "Color of Flesh"—see division 3.)

6. *Fiber.* Possible credits, 8.

Standards: Septa delicate and translucent; maximum diameter of core, $\frac{3}{16}$ inch in "large" fruit and $\frac{1}{8}$ inch in other.

7. *Grain.* Possible credits, 4.

Standards: Fineness, firmness, compactness.

8. *Seed.* Possible credits, 4.

Standard: Absence of seed.

Discount one point for each seed. Each rudiment to be considered as a seed if any growth has been developed; otherwise allowed without discount.

9. *Taste.* Possible credits, 30, divided as follows: Sweetness, 15; citrous quality, 15.

Standards: Clearness and definability of elements; sweetness rich, delicate rather than heavy; citrous quality, pronounced.

Deficiency or absence to be cause for discounts against any element, and excess to be like cause against sweetness, and against acid in "citrous quality."

Staleness and flavors of age or decay to be discounted from aggregate of points in this division.

LEMON SCALE.

Divisions: Size, form, color, weight, peel, fiber, grain, seed, taste.

Rules of counts and discounts as in scale for oranges. Total of possible credits, 100.

1. *Size.* Possible credits, 10.

Standards: Large, 250's, $2\frac{3}{8}$ inches in diameter.
Medium, 300's, $2\frac{1}{8}$ " " "
Small, 360's, $1\frac{7}{8}$ " " "

All sizes between 250's and 360's allowed.

Larger fruit to be discounted one point for each $\frac{1}{4}$ inch in excess. Smaller to be discounted one point for 400's ($1\frac{3}{4}$ inches) and four points for 450's ($1\frac{1}{2}$ inches).

2. *Form.* Possible credits, 5.

Standard: Oblong, with allowance of well-formed points at stem and tip. Symmetry required.

3. *Color.* Possible credits, 15.

Standard: Bright, clear lemon.

Discounts according to degree for green splashes, dashes of bronze, or deep shades, or for sunburn.

Rust, scale, and smut, with fruit that gives evidence of having been cleaned of the same, to be discounted five to ten counts.

Rubbing or dusting, if heavy enough to press oil from the cells, to be causes for discount.

4. *Weight.* Possible credits, 10.

Standard: Specific gravity, 1 (equal to that of water), with buoyancy of $\frac{1}{2}$ oz. allowed to "large" lemons and $\frac{1}{4}$ oz. to "medium" and "small," all without discount.

One point to be discounted for first $\frac{1}{2}$ oz. excess of allowance, and two points for each $\frac{1}{2}$ oz. thereafter.

5. *Peel.* Possible credits, 10; subdivisions of which are: Finish, 3 credits; protective quality, 7 credits.

Standard: For protective quality, to be strong, elastic, and reasonably firm texture; abundant, compact, and unbroken oil-cells; and thickness of $\frac{3}{32}$ to $\frac{3}{16}$ inch.

To be discounted two counts for first $\frac{1}{32}$ inch below minimum, and five counts for second $\frac{1}{32}$ inch; one count for first $\frac{1}{32}$ inch above maximum, and two for each succeeding $\frac{1}{32}$ inch.

Fresh-picked lemons not allowed.

6. *Fiber.* Possible credits, 8.

Standard: Septa delicate and translucent. Core not to exceed $\frac{3}{16}$ inch in "large" and $\frac{1}{8}$ inch in "medium" and "small" fruit.

7. *Grain.* Possible credits, 8, divided as follows: Fineness, firmness, and compactness, 4 credits; color, 4 credits.

Standard: Grain to be water-colored, shading to blue rather than to gray.

8. *Seed.* Possible credits, 4.

Standard: Absence of seed.

One half point to be discounted for each seed. (A discount of $\frac{1}{4}$ credit for each seed is now recommended as sufficient.)

Rudiments are to be considered as seed if any growth has been developed; otherwise allowed without discount.

9. *Taste.* Possible credits, 30, divided as follows: Acidity, 20 credits; absence of bitterness, 10 credits.

In interstate competitions the standard of acidity shall be the highest per cent of strength of acid found in any fruit, determined by chemical test. In other competitions such tests may be applied as committees or competitors may require.

Bitterness to be determined by slicing fruit (including peel) thin, covering with hot water, and cooling slowly; to stand twenty-four hours when practicable (no sugar to be used). Should *a trace* of bitterness appear to the taste, discount one point; should the bitterness be *fairly defined*, discount two points; if *pronounced*, discount five points; and if *strong*, ten points.